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STANFORD UNIV CALIF DEPT OF COMPUTER SCIENCE  
THE ERRATA OF COMPUTER PROGRAMMING. (U)

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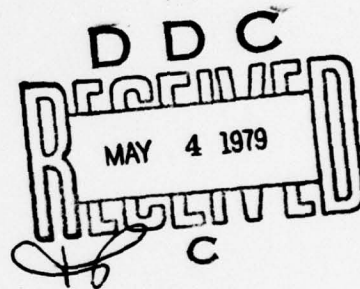
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THE ERRATA OF COMPUTER PROGRAMMING

by

Donald E. Knuth

STAN-CS-79-712  
January 1979



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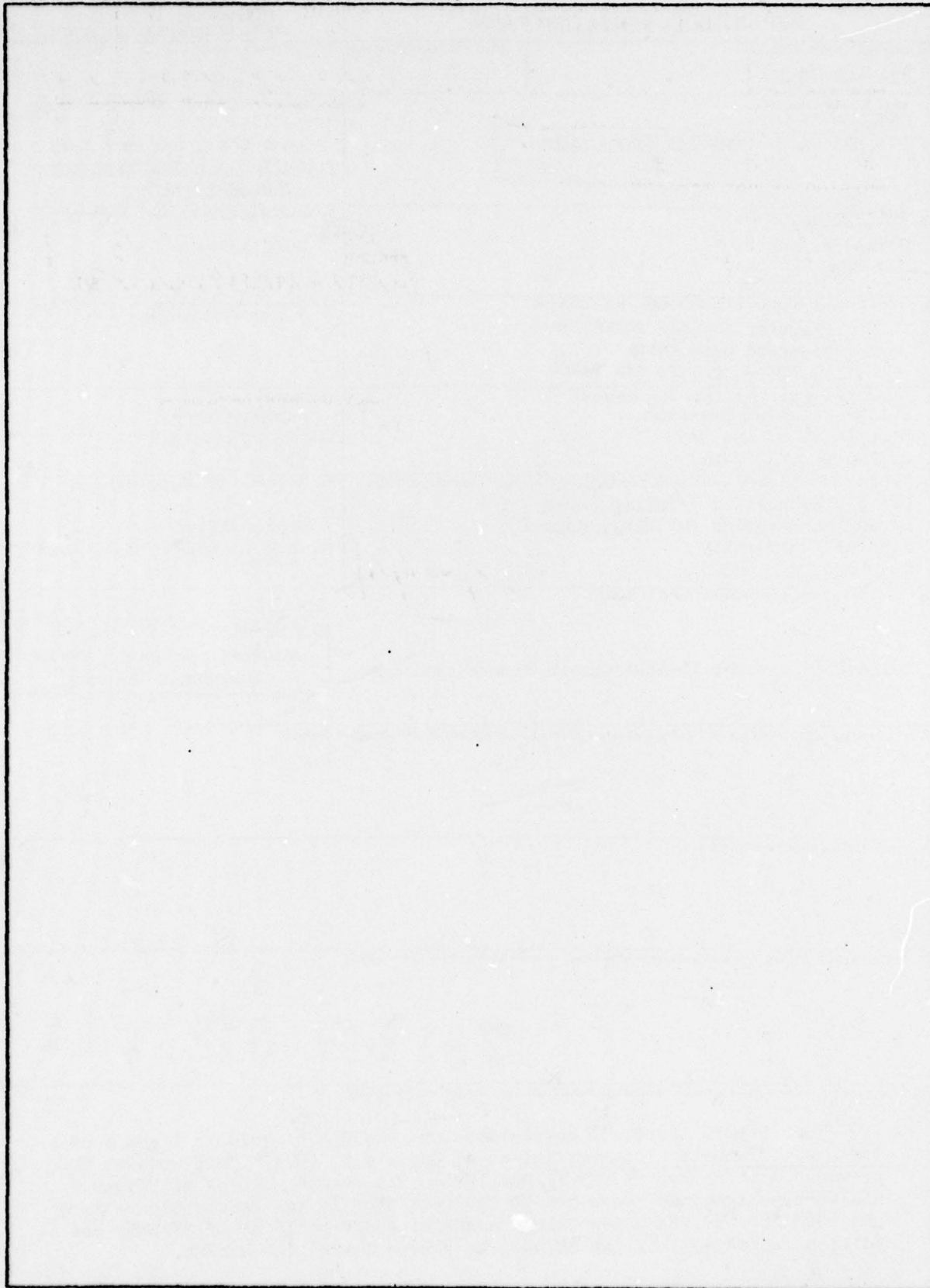
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## THE ERRATA OF COMPUTER PROGRAMMING

This report lists all corrections and changes of Volumes 1 and 3 of The Art of Computer Programming, as of January 5, 1979. This updates the previous list in report CS551, May 1976. The second edition of Volume 2 has been delayed two years due to the fact that it was completely revised and put into the TEX typesetting language; since publication of this new edition is not far off, no changes to Volume 2 are listed here.

The present report was prepared with a typesetting system that is now obsolete; please do not wince at the typography. All cahnges and corrections henceforth will be noted in TEX form on file ERRATA.TEX[ART,DEK] at SU-AI.

In spite of inflation, the rewards to error-detectors are still \$2 for "new" mistakes in the second edition, \$1 in the first edition.

Please do not endanger the author's morale by asking him about Volume 4. Thank you for your understanding.

**1.0** throughout the book(s)

2/28/78 2

when the text of these books is on a computer I will try to be consistent in hyphenating compound adjectives like doubly-linked lists and storage-allocation algorithms, etc. ... but until then, such lapses are not to be considered errors

**1.2** line 11

5/27/78 3

Leibnitz ~ Leibniz

**1.18** line -7

the theorem ~ that the theorem

**1.18** line 16

3... ~ 3...

**1.35** line 3, under the big pi

n, ~ n

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11/29/77 4

11/29/77 5

11/12/76 6

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**1.41** displayed formula in exercise 32 2/28/78 7

$n/c \rightsquigarrow n/c$

**1.44** add a footnote (see p. v for style) 4/19/77 8

line 3 after (1): book.  $\rightsquigarrow$  book.\*

footnote for bottom of page: In fact, permutations are so important, Vaughan Pratt has suggested calling them "perms." As soon as Pratt's convention is established, textbooks of computer science will be somewhat shorter (and perhaps less expensive).

**1.44** lines -4, -5(twice), -7, -15, -16 11/12/76 9

$\dots \rightsquigarrow \dots$

**1.45** lines 3, 10, 11, 12, 21 11/12/76 10

$\dots \rightsquigarrow \dots$

**1.50** exercise 21 line 1 7/31/76 11

$Faa \rightsquigarrow Fa\grave{a}$

**1.51** line 13 2/28/78 12

manner  $\rightsquigarrow$  matter

**1.52** line 6 after Table 1 8/25/76 13

Szu-yuen  $\rightsquigarrow$  Szu-yüan

**1.56** change in Eq. (17) 11/12/76 14

$-r \rightsquigarrow r$  and  $r \rightsquigarrow -r$

**1.57** Eq. (18) 7/31/76 15

$n \geq 0. \rightsquigarrow n.$

**1.57** line after (19) 11/12/76 16

$-r \rightsquigarrow r$

**1.66** caption to Table 2, replace third line by: 9/21/76 17

see D. E. Barton, F. N. David, and M. Merrington, *Biometrika* 47 (1960), 439-445; 50 (1963), 169-176.

**1.72** line -4 11/15/78 18

$A_{n(k-1)} \rightsquigarrow A_{n-1}(k-1)$

**1.79** lines 8,9,10 6/25/76 19

Kepler, ... life.  $\rightsquigarrow$  Johann Kepler, 1611, who was musing about the numbers he saw around him [J. Kepler, *The Six-Cornered Snowflake* (Oxford: Clarendon Press, 1966), p. 21].

**1.83** line -7 11/29/77 20

use same style script F in this line as in line -6 (six places)

**1.90** new generalized Eq. (29) 8/25/76 21

$(z/(e^z-1))^n = 1 - (1/(n-1))\binom{n}{n-1}z + (1/(n-1)(n-2))\binom{n}{n-2}z^2 - \dots = \sum_{k \geq 0} B_k^{(n)} z^k/k! \quad (29)$   
(convert this to usual format for displayed equations)

**1.90** update to previous correction number 25 11/12/76 22

to appear,  $\rightsquigarrow$  75-77,

**1.91** replace lines 1-3 by the following new copy

8/25/76 23

The coefficients  $B_k^{(n)}$  which appear in the last formula are called "generalized Bernoulli numbers"; Section 1.2.11.3 examines them further in the important special case  $n = 1$ . For small  $k$ , we have  $B_k^{(n)}/k! = (-1)^k \binom{n-k}{n-k} (n-k-1)!/(n-1)!$ , but when  $k \geq n$  this formula breaks down since it reduces to 0 times  $\infty$ . An analogous situation holds for the power series  $(z/\ln(1+z))^n$ , where the coefficient of  $z^k$  for  $k < n$  is  $\binom{n-k}{n-k} (n-k-1)!/(n-1)!$ .

**1.92** line -8

7/31/76 24

$F_{aa} \rightsquigarrow F_{aa}$

**1.98** caption, line 2

7/31/76 25

2.11  $\rightsquigarrow$  2.10

**1.103** line 3

7/31/76 26

$F_{aa} \rightsquigarrow F_{aa}$

**1.110** three lines after (12)

6/25/76 27

$R_m \rightsquigarrow |R_m|$

**1.111** line 8

11/15/78 28

mately 2  $\rightsquigarrow$  mately  $(-1)^{1+k/2}$

**1.116** line -6

11/29/77 29

Analysis  $\rightsquigarrow$  A crude analysis

**1.116** line -6 and Eq. (22)

11/29/77 30

$n^{n-1/2} \rightsquigarrow n^n$

**1.117** line 5 11/29/77 31

three ~ two

**1.118** exercise 5 11/29/77 32

$n^{n-1/2}$  ~  $n^n$

**1.125** line 2 11/16/77 33

is loaded. ~ are loaded.

**1.126** line 1 11/16/77 34

The contents ~ A portion of the contents

**1.126** line 7 11/16/77 35

is ~ are

**1.127** line -19 11/15/78 36

Overflow may occur as in ADD. ~ Same as ADD but with -V in place of V.

**1.127** lines -18 through -13 11/15/78 37

move this paragraph in front of the SUB definition on the preceding two lines

**1.134** line -12 4/19/77 38

MUL requires ~ MUL, NUM, CHAR each require

**1.137** box 05 4/19/77 39

1 ~ 10

**1,150** lines -10,-9,-8 4/19/77 40

CON ~ CON (4 times)

**1,152** line 16 11/29/77 41

facilate ~ facilitate

**1,156** stylistic corrections 6/14/77 42

line 2: i.e. ~ e.g.

line 3: (X ~ (Here X

line 5: sun. ~ sun;

line 10: (E ~ (This number E

line 22: the year ~ that the year

**1,198** lines 19-21 6/14/77 43

An illustration...See also the book ~ See, for example, the book

**1,224** line -11 6/14/77 44

F - 7 ~ F - 9

**1,225** line -9 6/25/76 45

about 1946 ~ during 1946 and 1947

**1,237** line -10 12/19/76 46

down an item ~ an item down

up the stack ~ the stack up

**1,248** insert new paragraph after line 4 4/19/77 47

Further study of Algorithm G has been made by D. S. Wise and D. C. Watson, *BIT* 16 (1976), 442-450.

**1,258** line 4

9/21/76 48

we ~ exercise 30 describes a somewhat more natural alternative, and we

**1,270** new exercise

9/21/76 49

30. [17] Suppose that queues are represented as in (12), but with an empty queue represented by  $F = A$  and  $R$  *undefined*. What insertion and deletion procedures should replace (14) and (17)?

**1,303** exercise 9 line 4

3/ 2/77 50

girls ~ women

**1,325** line 8

4/19/77 51

otherwise. ~ otherwise, making the latter node the right son of NODE (Q).

**1,332** new quote to insert just before Section 2.3.2

1/16/77 52

*Binary or dichotomous systems, although regulated by a principle, are among the most artificial arrangements that have ever been invented.*

--WILLIAM SWAINSON, *A Treatise on the Geography and Classification of Animals*, Sec. 250 (1835)

**1,339** line 13

6/25/76 53

In all ~ Furthermore TYPE (W) is set appropriately, depending on  $x$ . In all

**1,382** line 2

12/19/76 54

there is a man now living having ~ somebody now living has

**1,398** line -1

5/27/78 55

with ~ than

**1,406** line -2

1/16/77 56

as  $\rightsquigarrow$  informally as

**1,406** line 11

5/27/78 57

-types  $\rightsquigarrow$  -tuples

**1,406** line 18

11/15/78 58

Polya  $\rightsquigarrow$  Pólya

**1,414** step A2 lines 2-4

2/28/78 59

unmarked, mark it, and if  $\rightsquigarrow$  unmarked: mark it and, if (twice)

**1,420** lines 14-15

9/21/76 60

[See the ... 372.]  $\rightsquigarrow$  An elaborate system which does this, and which also includes a mechanism for postponing operations on reference counts in order to achieve further efficiency, has been described by L. P. Deutsch and D. G. Bobrow in *CACM* 19 (1976), 522-526.

**1,420** line 17

11/29/77 61

see  $\rightsquigarrow$  see N. E. Wiseman and J. O. Hiles, *Comp. J.* 10 (1968), 338-343,

**1,437** line 18

6/25/76 62

For these reasons the  $\rightsquigarrow$  A contrary example appears in exercise 7; the point is that neither method clearly dominates the other, hence the simple

**1,445** line 11

1/16/77 63

each with a random lifetime,  $\rightsquigarrow$  each equally likely to be the next one deleted,

**1,446** new paragraph after line 6

1/16/77 64

Our assumption that each deletion applies to a random reserved block will be valid if the lifetime of a block is an exponentially-distributed random variable. On the other hand, if all blocks have roughly the same lifetime, this assumption is false; John E. Shore has pointed out that type A blocks tend to be "older" than type C blocks when allocations and deletions tend to have a somewhat first-in-first-out character, since a sequence of adjacent reserved blocks tends to be in order from youngest to oldest and since the most recently allocated block is almost never type A. This tends to produce a smaller number of available blocks, giving even better performance than the fifty-percent rule would predict. [Cf. *CACM* 20 (1977), 813-820.]

**1,448** line -9

1/15/78 65

areas  $\rightsquigarrow$  areas of the same size

**1,451** line 7

1/16/77 66

.  $\rightsquigarrow$  ; John E. Shore, *CACM* 18 (1975), 433-440.

**1,451** yet another addition after line 7

2/28/78 67

.  $\rightsquigarrow$  ; Norman R. Nielsen, *CACM* 20 (1977), 864-873.

**1,454** exercise 28

4/19/77 68

line 2: 5; for  $\rightsquigarrow$  5. For  
line 4: "  $\rightsquigarrow$  The execution time is  $2u$ ."

**1,456** line 8

6/25/76 69

V-1.]  $\rightsquigarrow$  V-1; and see especially also the work of Konrad Zuse, *Berichte der Gesellschaft für Math. und Datenv.* 63 (Bonn, 1972), written in 1945. Zuse was the first to develop nontrivial algorithms that worked with lists of dynamically varying lengths.]

**1,456** line -7

12/19/76 70

is divisible  $\rightsquigarrow$  is not divisible

1.458

6/25/76 71

lines -15 thru -13: The A-1 ... code;  $\rightsquigarrow$  The machine language for several early computers used a three-address code to represent the computation of arithmetic expressions;

lines -11 and -10: the A-1 compiler language  $\rightsquigarrow$  an extended three-address code

1.460 line 2

3/ 2/77 72

The latter  $\rightsquigarrow$  Weizenbaum's

1.463 several changes

12/19/76 73

line 1: .  $\rightsquigarrow$  ,

line 4: older  $\rightsquigarrow$  other

new paragraph to be inserted after line 4:

A related model of computation was proposed by A. N. Kolmogorov as early as 1952. His machine essentially operates on graphs  $G$ , having a specially designated starting vertex  $v_0$ . The action at each step depends only on the subgraph  $G'$  consisting of all vertices at distance  $\leq n$  from  $v_0$  in  $G$ , replacing  $G'$  in  $G$  by another graph  $G'' = f(G')$ , where  $G''$  includes  $v_0$  and the vertices  $v$  at distance exactly  $n$  from  $v_0$ , and possibly other vertices; the remainder of graph  $G$  is left unaltered, its components are attached to the vertices  $v$  at distance  $n$  as before. Here  $n$  is a fixed number specified in advance for any particular algorithm, but it can be arbitrarily large. A symbol from a finite alphabet is attached to each vertex, and restrictions are made so that no two vertices with the same symbol can be adjacent to a common vertex. (See A. N. Kolmogorov, *Uspekhi Mat. Nauk* 8,4 (1953), 175-176; Kolmogorov and Uspenskii, *Uspekhi Mat. Nauk* 13,4 (1958), 3-28, *Amer. Math. Soc. Translations*, series 2, 29 (1963), 217-245.) Such graph machines can easily simulate the linking automata defined above, taking one graph step per linking step; conversely, linking automata can simulate graph machines, taking at most a bounded number of steps per graph step when  $n$  and the alphabet size are fixed. The linking model is, of course, quite close to the operations available to programmers on real machines, while the graph model is not.

1.473 exercise 44 line 2

11/12/76 74

$x_k + y_i \rightsquigarrow x_j + y_k$

1.478 line 8

1/16/77 75

(to appear)  $\rightsquigarrow$  13 (1975), 251-261.

1,482 line 1

7/31/76 76

Fas  $\rightsquigarrow$  Faa

1,487 new answer, continued

4/19/77 77

For example, Eq. (6) holds for all complex  $k$  and  $n$ , except in certain cases when  $n$  is a negative integer; Eqs. (7), (9), (20) are never false, although they may occasionally take indeterminate forms such as  $0 \cdot \infty$  or  $\infty \cdot \infty$ . We can even extend the binomial theorem (13) and Vandermonde's convolution (21), obtaining  $\sum_k \binom{r}{a+k} x^{a+k} = (1+x)^r$  and

$\sum_k \binom{r}{a+k} \binom{s}{b-k} = \binom{r+s}{b}$ , formulas which hold for all complex  $r, s, a, b$  whenever the series converge, provided that complex powers are properly defined. [See L. Ramshaw, *Inf. Proc. Letters* 6 (1977), 223-226.]

1,487 new answer

11/12/76 78

42.  $1/(r+1)B(k+1, r-k+1)$ , if this is defined according to exercise 41(b). In general it appears best to define  $\binom{r}{k} = 0$  when  $k$  is a negative integer, otherwise  $\binom{r}{k} = \lim_{s \rightarrow r} \Gamma(s+1)/\Gamma(k+1)\Gamma(s-k+1)$ , since this preserves most of the important identities.

1,494 line 9

11/15/78 79

Polya  $\rightsquigarrow$  Pólya

1,499 exercise 7

11/15/78 80

(It is "Glaisher's constant" 1.2824271...) To  $\rightsquigarrow$  To  
This formula ...  $n=4$ .  $\rightsquigarrow$  (The constant  $A$  is "Glaisher's constant" 1.2824271..., which R. W. Gosper has proved equal to  $(2\pi)^{-1/2} \Gamma'(2)/\Gamma(2)^{1/2}$ .)

1,500 exercise 5

11/29/77 81

line 1:  $2n-1 \rightsquigarrow 2n+1$

line 2: has ...  $dx$ .  $\rightsquigarrow$  changes sign at  $r = n - O(\sqrt{n})$ , so  $R = O(\int_0^n |f'(x)| dx) = O(|f'(r)|) + O(|f'(n)|) = O(f(n)/\sqrt{n})$ .

1,502 exercise 17(b) line 6

3/ 2/77 82

J2NN  $\rightsquigarrow$  J2P

**1.502** exercise 19

4/19/77 83

24  $\rightsquigarrow$  421+1)u  $\rightsquigarrow$  10+10)u**1.504** exercise 25

4/19/77 84

lines 11-12: operations"  $\rightsquigarrow$  operations," jumps on register even or odd, and binary shifts  
 last line: M.  $\rightsquigarrow$  M, and others could set register+rA, register+rX.

**1.504**

6/14/77 85

line 1: 6  $\rightsquigarrow$  5 (also make this change in previous correction no. 111)line 6: 3494  $\rightsquigarrow$  3495 and 6  $\rightsquigarrow$  5line 7: 3495  $\rightsquigarrow$  3496 and 5  $\rightsquigarrow$  4line 9: 3506  $\rightsquigarrow$  3505 and 6  $\rightsquigarrow$  5line 10: 16  $\rightsquigarrow$  14**1.511** changes to answer 14

6/14/77 86

line 1: uses as much  $\rightsquigarrow$  due in part to J. Petolino uses a lot ofline 2: as possible, in  $\rightsquigarrow$  inline 9: INCX 1  $\rightsquigarrow$ line 10: G  $\rightsquigarrow$  GMINUS1

lines -17 to end of page, replace by:

```

CPLUS60  INCA 61
          STA CPLUS60
          MUL -3//4+1=
          STA XPLUS57(1:2)
GMINUS1  ENTA *
          MUL -8//25+1=
          ENT2 *
          ENT1 1,2
          INC2 1,1
          INC2 0,2
          INC2 0,1
          INC2 0,2
          INC2 773,1
XPLUS57  INCA -*,2

```

rA = Z + 24

E5.

rI1 = G

rI2 = 11G + 773

rA = 11G+Z-X+20+24-30 ( $\geq 0$ )

**1,512** more changes to answer 14

6/14/77 87

delete the bottom line and replace lines 1-31 by:

	SRAX 5	
	DIV -30-	$rX = E$
	DECX 24	
	JXN 4F	
	DECX 1	
	JXP 2F	
	JXN 3F	
	DEC1 11	
	JINP 2F	
3H	INCX 1	
2H	DECX 29	E6.
4H	STX 20MINUSN(0:2)	
	LDA Y	E4.
	MUL -1//4+1-	
	ADD Y	
	SUB XPLUS57(1:2)	$rA = D-47$
20MINUSN	ENN1 *	
	INCA 67,1	E7.
	SRAX 5	$rX = D + N$
	DIV -7-	
	SLAX 5	
	DECA -4,1	$rA = 31 - N$
	JAN 1F	E8.
	DECA 31	
	CHAR	
	LDA MARCH	
	JMP 2F	
1H	CHAR	
	LDA APRIL	

**1,513** new answer

6/14/77 88

15. The first such year is A.D. 10317, although the error almost leads to failure in A.D. 10108+19k for  $0 \leq k \leq 10$ .

**1.513** still more changes to answer 14

6/14/77 89

replace lines 1-6 by:

BEGIN

ENTX 1950  
ENTG 1950-2000  
JMP EASTER  
INCG 1  
ENTX 2000,6  
JGMP EASTER+1

"driver"  
routine,  
uses the  
above  
subroutine.

**1.514** line 18

11/29/77 90

time.  $\rightsquigarrow$  time. (It would be faster to calculate  $r_m(1/m)$  directly when  $m$  is small, and then to apply the suggested procedure.)

**1.515** bottom line

11/29/77 91

Berk'ly  $\rightsquigarrow$  Berkeley

**1.516** lines -4,-3

4/19/77 92

3)\*7  $\rightsquigarrow$  7.5)\*16

**1.517** exercise 12 lines 7-10

5/27/78 93

delete "Thus, ...(b)."

**1.518** line 5

5/27/78 94

19-27.  $\rightsquigarrow$  19-27; E. G. Cate and D. W. Twigg, *ACM Trans. Math. Software* 3 (1977), 104-110.

**1.546** new answer

9/21/76 95

30. To insert, set  $P \leftarrow \text{AVAIL}$ ,  $\text{INFO}(P) \leftarrow Y$ ,  $\text{LINK}(P) \leftarrow A$ , if  $F = A$  then  $F \leftarrow P$  else  $\text{LINK}(R) \leftarrow P$ , and  $R \leftarrow P$ . To delete, do (9) with  $F$  replacing  $T$ .

**1,550 exercise 18**

3/ 2/77 96

denotes, ... are included.  $\rightsquigarrow$  denotes "exclusive or." Other invertible operations, such as addition or subtraction modulo the pointer field size, could also be used. It is convenient to include

**1,550 exercise 2**

3/ 2/77 97

line 2: next ... list point  $\rightsquigarrow$  next, so the links in the list must point  
line 3: So ... the  $\rightsquigarrow$  Deletion at both ends therefore implies that the  
line 4: ways.  $\rightsquigarrow$  ways. On the other hand, exercise 2.24-18 shows that two links can be represented in a single link field; in this way general deque operations are possible.

**1,553 exercise 9 step G4**

3/ 2/77 98

desired girls,  $\rightsquigarrow$  young ladies desired,

**1,558 line -6**

5/27/78 99

"podigrees",  $\rightsquigarrow$  "podigrees,"

**1,575 exercise 12 line 5**

9/21/76 100

$\infty$ .  $\rightsquigarrow$   $\infty$ . Here  $c(i,j)$  means  $c(j,i)$  if  $j < i$ .

**1,583 answer 5**

1/ 5/79 101

There is ... exist.  $\rightsquigarrow$  When  $n > 1$ , the number of series-parallel networks with  $n$  edges is  $2c_n$  [see P. A. MacMahon, *Proc. London Math. Soc.* 22 (1891), 330-339].

**1,588 fourth line before exercise 33**

5/27/78 102

minimal.  $\rightsquigarrow$  minimal. [This argument in the case of binary trees was apparently first discovered by C. S. Peirce in an unpublished manuscript; see his *New Elements of Mathematics* 4 (The Hague: Mouton, 1976), 303-304.]

**1.594** updates to previous change number 150 9/21/76 103

to appear,  $\rightsquigarrow$  491-500,  
(see also the important new contribution by H. G. Baker, Jr., *CACM* 21 (1978), 280-294, for which I will probably want to revise Section 2.3.5 entirely!)

**1.594** update to previous change number 151 11/29/77 104

Clark's list-copying algorithm appeared in *CACM* 21 (1978), 351-357, and Robson's in *CACM* 20 (1977), 431-433

**1.597** last line of answer 6 1/16/77 105

list.  $\rightsquigarrow$  list. For an alternative improvement to Algorithm A, see exercise 6.2.3-30.

**1.597** exercise 8 6/25/76 106

line 1: also set  $R \rightsquigarrow$  also set  $M \leftarrow \infty, R$   
line 3: If  $R = A$  or  $M \rightsquigarrow$  If  $M$

**1.601** exercise 26 line 3 2/28/78 107

two.  $\rightsquigarrow$  two, with blocks in decreasing order of size.  
 $P \geq M \rightsquigarrow P \geq M - 2^k$ .

**1.601** program line number 12 4/19/77 108

$j \rightsquigarrow j$ .

**1.602** new answer 2/28/78 109

31. See David L. Russell, *SIAM J. Computing* 6 (1977), 607-621.

**1.603** addition to previous change 153 4/19/77 110

.]  $\rightsquigarrow$  ; Lars-Erik Thorelli, *BIT* 16 (1976), 426-441.

**1.606** exercise 41, numerator in value of a[5] 6/14/77 111

19559 ~ 18535

**1.617L** 6/25/76 112

delete A-1 compiler, 458.

**1.617L** Aardenne-... 11/29/77 113

Taniana ~ Tatyana

**1.617R** 12/19/76 114

AMM ~ AMM

**1.618L** 5/27/78 115

Baker, Henry Givens, Jr., 594.

**1.618R** 4/19/77 116

add p487 to entry for Binomial theorem, generalizations of

**1.619L** Bobrow entry 9/21/76 117

add p420

**1.619R** 5/27/78 118

Cato, Eako George, 518.

**1.619R** 11/29/77 119

Cheney, Christopher John, 420.

**1.620R** new definition entry

12/19/76 120

Data organization: A way to represent information in a data structure, together with algorithms that access and/or modify this structure.

**1.621L**

2/28/78 121

Derangements, 177.

**1.621L** Deutsch entry

9/21/76 122

add p420

**1.622L** End of file entry

3/ 2/77 123

224 ~ 223

**1.623R** Garwick entry

11/15/78 124

244 ~ 245

**1.624L** Hopper entry

6/25/76 125

255,458. ~ 225.

**1.624L**

11/29/77 126

Hiles, John Owen, 420.

**1.624R**

3/ 2/77 127

Invert a linked list, 266, 276.

**1.624R** INT entry

6/14/77 128

225. ~ 224-225.

**1.625R**

5/27/78 129

Leibnitz (= Leibnis) ~ Leibnis (= Leibnitz)

**1.625R**

12/19/76 130

Kolmogorov, Andrei Nikolaevich, 463.

**1.626R** MacMahon entry

1/ 5/79 131

add p. 583

**1.627L**

9/21/76 132

Merrington, Maxine, 66.

**1.628L**

2/28/78 133

Nielsen, Norman Russell, 451.

**1.628R**

5/27/78 134

Peirce, Charles Santiago Sanders, 588.

**1.629**

4/19/77 135

add p44 to Pratt entry

**1.629L**

6/14/77 136

Petolino, Joseph Anthony, Jr., 511.

**1.629R**

5/27/78 137

Prüfer, Heinz ~ Prüfer, Ernst Paul Heinz

**1.629B**

6/25/76 138

Prinz, Dietrich G.

**1.630L**

4/19/77 139

Ramshaw, Lyle Harold, 487.

**1.630B**

3/1 2/77 140

Reversing a list, 266, 276.

**1.631L** new entry

1/1 5/79 141

Series-parallel networks, 583.

**1.631L**

1/16/77 142

Shore, John E., 446, 451.

**1.631L**

2/28/78 143

Russell, David Lewis, 602.

**1.632L**

1/16/77 144

Swainson, William, 332.

**1.632L** Stirling numbers entry

8/25/76 145

90, ~ 90-91,

**1.632B**

4/19/77 146

add p630 to Thorelli entry

**1,633R**

4/19/77 147

Watson, Dan Caldwell, 248.

**1,633R**

4/19/77 148

add p487 to Vandermonde entry

**1,633R**

5/27/78 149

Twigg, David William, 518.

**1,633R** van Aardenne-...

11/29/77 150

Taniana ~ Tatyana

**1,633R**

12/19/76 151

Uspenskii, Vladimir Andreovich, 463.

**1,634L**

4/19/77 152

add p248 to Wise entry

**1,634L**

6/25/76 153

Windley, Peter F.

**1,634L** Weizenbaum entry

9/21/76 154

delete p420

**1,634L**

11/29/77 155

Wiseman, Neil Ernest, 420.

**1.634R**

6/25/76 156

Young Tanner, Rosalind Cecilia Hildegard, 75.

**1.636** (namely the endpapers of the book)

4/19/77 157

also make any changes specified for pages 136-137

**S.0X** quotation for bottom of page

5/27/78 158

*Two hours' daily exercise . . . will be enough  
to keep a hack fit for his work.*  
--M. H. MAHON, *The Handy Horse Book* (Edinburgh, 1865)

**S.8L** line 21

3/ 2/77 159

mädeln ~ Mädeln

**S.8R** line 26

3/ 2/77 160

Weiner ~ Wiener

**S.24** line 13

2/28/78 161

(1965 ~ (1965)

**S.34** bottom line of determinant on line 12

5/27/78 162

$a_{mn}$  ~  $a_{mm}$

**S.40** Eq. (26)

2/28/78 163

the  $j$  in  $e^j$  should be in smaller (superscript size) font

**S.57** line 2 of step S3

2/28/78 164

right ~ right of

3.58 line 4

2/28/78 165

$a_1 a_2 \rightsquigarrow a_1, a_2$

3.63 line -4

5/27/78 166

S's  $\rightsquigarrow$  X's

X's  $\rightsquigarrow$  S's

3.65 line -8

2/28/78 167

to better understand  $t_n \rightsquigarrow$  to understand  $t_n$  better

3.67 following (50)

5/27/78 168

lines 2-4: we find...Euler's  $\rightsquigarrow$  Euler's

line 5: in this case, since  $\rightsquigarrow$  since

lines 7-8 (the two lines following (51)):  $n$ ; this...we have proved that  $\rightsquigarrow$

$n$ . The derivative  $g^{(m)}(y)$  is a polynomial in  $y$  times  $e^{-2y^2}$ , hence  $R_m = O(n^{(t+1-m)/4})$   
 $\int_{-\infty}^{+\infty} |g^{(m)}(y)| dy = O(n^{(t+1-m)/4})$ . Furthermore if we replace  $\alpha$  and  $\beta$  by  $-\infty$  and  $+\infty$  in  
the right-hand side of (50), we make an error of at most  $O(\exp(-2n^t))$  in each term. Thus

3.69 exercise 8

6/14/77 169

accent over  $o$  in Erdős should be "not "

3.72 new copy for exercise 28

11/15/78 170

28. [M43] Prove that the average length of the longest increasing subsequence of a random permutation on  $\{1, 2, \dots, n\}$  is asymptotically  $2\sqrt{n}$ . (This is the average length of row 1 in the correspondence of Theorem A.)

3.79 last line before exercises

9/21/76 171

Feurzig  $\rightsquigarrow$  Feurzeig

3.83 lines 7 and 12

11/29/77 172

$\log_2 \rightsquigarrow \lg$

**3.98** line 4

11/29/77 173

$\log_2 \rightsquigarrow \lg$

**3.104** line -2

6/14/77 174

inversions.  $\rightsquigarrow$  inversions. Discuss corresponding improvements to Program S.

**3.117** simplifications of step Q2

12/19/76 175

line 3:  $K \leftarrow K_i, R \leftarrow R_i. \rightsquigarrow K \leftarrow K_i.$

line 4:  $K$  and  $R \rightsquigarrow K$

**3.118** comment to program line 05

12/19/76 176

$K \leftarrow K_i, R \leftarrow R_i. \rightsquigarrow K \leftarrow K_i.$

**3.120** line -3

6/14/77 177

$S_N \rightsquigarrow S_N$

**3.122** line -6

12/19/76 178

instructions " $K \leftarrow K_i, R \leftarrow R_i$ "  $\rightsquigarrow$  instruction " $K \leftarrow K_i$ "

**3.128** line -3

4/19/77 179

$v. \rightsquigarrow v.$  Yih-siao Wang has suggested that the mean of three key values such as (28) be used as the threshold for partitioning; he has proved that the number of comparisons required to sort uniformly distributed random data will than be asymptotic to  $1.082 n \lg n$ .

**3.132** 10 lines after (42)

5/27/78 180

$(N/x)^t \rightsquigarrow (N/xe)^t$

**3.132** 7 lines after (42)

5/27/78 181

$O(N^{t-1/2}e^{-\pi N/2}) \rightsquigarrow O(|t+iN|^{t-1/2}e^{-t-\pi N/2})$

**S.133** in the discussion following (45) 5/27/78 182

line 3:  $N^4 \rightsquigarrow |M+IN|^4$

line 4: negligible.  $\rightsquigarrow$  negligible, when  $N$  and  $N'$  are much larger than  $M$ .

**S.134** Eq. (46) and the line following 2/28/78 183

,  $\rightsquigarrow + O(n^{-M})$ ,

where  $\rightsquigarrow$  for arbitrarily large  $M$ , where

**S.134** displayed formula on line 12 2/28/78 184

$f(n) \rightsquigarrow |f(n)|$

1725  $\rightsquigarrow$  173

**S.135** exercise 16 11/29/77 185

HM46  $\rightsquigarrow$  HM42

**S.138** exercise 46 lower limit of integral 6/14/77 186

$a+i\infty \rightsquigarrow a-i\infty$

**S.138** exercise 52 binomial coefficient in the sum 6/14/77 187

remove spurious fraction line between  $2n$  and  $n+t$

**S.144** line 10 2/28/78 188

Language,  $\rightsquigarrow$  Language

**S.153** 11/12/76 189

about here I will someday insert material about the new "binomial queue" algorithms to be discussed in papers by Vuillemin and Brown, since they appear to outperform leftist trees

**3.158** line -5 5/27/78 190

$a_i \rightsquigarrow a_1$

**3.167** line 21 of program 5/27/78 191

$L_q \rightsquigarrow L_p$

**3.176** line -12 5/27/78 192

$M-b \rightsquigarrow M-b'$

**3.177** lines 25-27 9/21/76 193

that the multiplicity ... Algorithm R, even  $\rightsquigarrow$   
that it ultimately spends too much time fussing with very small piles. Algorithm R is  
relatively efficient, even

**3.192** line -7 5/27/78 194

Well's  $\rightsquigarrow$  Wells's

**3.193** line -15 5/27/78 195

less  $\rightsquigarrow$  fewer

**3.199** Eq. (4) 2/28/78 196

$\lg r \rightsquigarrow r \lg$

**3.208** replacement for exercise 14 11/29/77 197

14. [41] (F. K. Hwang.) Let  $h_{3k} = \lfloor (43/28) \cdot 2^k \rfloor - 1$ ,  $h_{3k+1} = h_{3k} + 3 \cdot 2^{k-3}$ ,  $h_{3k+2} = \lfloor (17/7) \cdot 2^k - 6/7 \rfloor$  for  $k \geq 3$ , and let the initial values be defined so that  $(h_0, h_1, h_2, \dots) = (1, 1, 2, 2, 3, 4, 5, 7, 9, 11, 14, 18, 23, 29, 38, 48, 60, 76, 97, 121, 154, \dots)$ . Prove that  $M(3, h_k) > \epsilon$  and  $M(3, h_k - 1) \leq \epsilon$  for all  $\epsilon$ , thereby establishing the exact values of  $M(3, n)$  for all  $n$ .

**S.215** bottom line of Table 1

3/ 2/77 198

17  $\rightsquigarrow$  16\*\* (twice)

add footnote:

\*\* See K. Noshita, *Trans. of the IECE of Japan*, E59, 12 (Dec. 1976), 17-18.

**S.215** line 4 after second illustration

3/ 2/77 199

the values listed in the table for  $n \geq 8$   $\rightsquigarrow$  the values shown for  $V_4(9)$ ,  $V_5(10)$  and their duals  $V_6(9)$ ,  $V_6(10)$

**S.217** amendment to previous correction number 242

12/19/76 200

line 17: A. Schönhage [to appear]  $\rightsquigarrow$  A. Schönhage, M. Paterson, and N. Pippenger [*J. Comp. Sys. Sci.* 13 (1976), 184-199]

line 18: asymptotic  $\rightsquigarrow$

lines 19-20:  $3n$ , and ...  $1.75n$ .  $\rightsquigarrow$   $3n + O(n \log n)^{3/4}$ . On the other hand, Vaughan Pratt has obtained an asymptotic lower bound of  $1.75n$  for this problem [cf. *Proc. IEEE Conf. Switching and Automata Theory* 14 (1973), 70-81]; a generalization of his result appears in exercise 25.

**S.219** exercise 14

12/19/76 201

Show that ... comparisons.  $\rightsquigarrow$  Let  $U_t(n)$  be the minimum number of comparisons needed to find the  $t$  largest of  $n$  elements, without necessarily knowing their relative order. Show that  $U_2(5) \leq 5$ .

**S.220** new exercise

12/19/76 202

25. [M32] (A. Schönhage, 1974.) (a) In the notation of exercise 14, prove that  $U_t(n) \geq \min(2+U_t(n-1), 2+U_{t-1}(n-1))$  for  $n \geq 3$ . *Hint:* Construct an adversary by reducing from  $n$  to  $n-1$  as soon as the current partial ordering is not composed of components  $\bullet$  or  $\bullet \rightarrow \bullet$ . (b) Similarly, prove that  $U_t(n) \geq \min(2+U_t(n-1), 3+U_{t-1}(n-1), 3+U_t(n-2))$  for  $n \geq 5$ , by constructing an adversary which deals with components  $\bullet$ ,  $\bullet \rightarrow \bullet$ ,  $\bullet \rightarrow \bullet \rightarrow \bullet$ ,  $\bullet \rightarrow \bullet \rightarrow \bullet \rightarrow \bullet$ . (c) Therefore we have  $U_t(n) \geq n + t + \min(\lfloor (n-t)/2 \rfloor, t) - 3$  for  $1 \leq t \leq n/2$ . (d) The inequalities in (a) and (b) apply also when  $V$  or  $W$  replaces  $U$ , thereby establishing the optimality of several entries in Table 1.

**S.225** line 1

5/27/78 203

$\lfloor m/2 \rfloor \rightsquigarrow 2\lfloor m/2 \rfloor$

$\lfloor n/2 \rfloor \rightsquigarrow 2\lfloor n/2 \rfloor$

**S.229** remarks about current best known sorting networks

1/16/77  
204

line 19: D. Van Voorhis in 1974.  $\rightsquigarrow$  R. L. Drysdale III in his undergraduate honors project at Knox College in 1973.

lines 20-21:  $\alpha n \lg n + O(n)$  comparators, ...3651,  $\rightsquigarrow$

$(371/960)n \lg n + O(n)$  comparators; in particular, his construction yields  $S(256) \leq 3657$ ,

line 22: [To be published.]  $\rightsquigarrow$  [SIAM J. Computing 4 (1975), 264-270.]

**S.232** update to previous change number 250

8/25/76 205

[JACM, to appear]  $\rightsquigarrow$  [JACM 23 (1976), 566-571]

**S.233** line 9

5/27/78 206

)  $\rightsquigarrow$  )

**S.243** rating of exercise 48

1/16/77 207

II M49  $\rightsquigarrow$  II M46

**S.259** lines 4, 5, 6, 7

9/21/76 208

has not yet ...  $m = 8$ . This increase  $\rightsquigarrow$   
is difficult to analyze precisely, but T. O. Espelid has shown how to extend the snowplow analogy to obtain an approximate formula for the behavior [BIT 16 (1976), 133-142]. According to his formula, which agrees well with empirical tests, the run length will be about  $2P + b(m-1.5)(2P+b(m-2))/(2P+b(2m-3))$ , when  $b$  is the block size and  $m \geq 2$ . Such an increase

**S.260** insert new paragraph before Table 2

2/28/78 209

The ideas of delayed run-reconstitution and natural selection can be combined, as discussed by T. C. Ting and Y. W. Wang in *Comp. J.* 20 (1977), 298-301.

<b>S.262</b> line 7	5/27/78 210
should be the square root of $(4e-10)P$	
<b>S.264</b> line -1	5/27/78 211
beings $\rightsquigarrow$ begins	
<b>S.279</b> line 10 after Table 4	6/14/77 212
<i>JACM</i> (to appear) $\rightsquigarrow$ <i>SIAM J. Computing</i> 6 (1977), 1-39	
<b>S.282</b> line before the big tableau	5/27/78 213
"R," $\rightsquigarrow$ "R",	
<b>S.284</b> line 22	11/5/79 214
143 $\rightsquigarrow$ 145	
<b>S.284</b> lines 4, 13, 20	11/5/79 215
25 $\rightsquigarrow$ 27	
<b>S.303</b> line -4	8/25/76 216
always get $\rightsquigarrow$ always gets	
<b>S.326</b> line -7	11/29/77 217
$L[p]$ $\rightsquigarrow$ $L[m]$	
<b>S.338</b> lines 1 and 7	6/14/77 218
! $\rightsquigarrow$ .	

**S.341** the foldout illustration

7/31/76 219

in the bottom example (#10) look at line 4 of the six lines, where there is a longish black bar as the seventh activity (the sixth activity is a shorter black bar)...and lines 1,2,3, and 5 have a blank bar just above and below this longish black bar; actually lines 1,2,3, and 5 should have parallel upward-slanting diagonal lines (the symbol for "reading in forward direction") inside these blank bars

**S.348** line 9 after the first illustration

5/27/78 220

tape C  tape A  
tape D  tape B


**S.352** line -9

6/14/77 221

is  in


**S.352** exercise 3

11/29/77 222

merge  radix sort

**S.356** line -11

5/27/78 223

T3  Track 3

**S.358** line -20

12/19/76 224

artificially  tificially

**S.370** Equation (8)

8/25/76 225

$B_2^2$    $B_1^2$

**S.373**

6/25/76 226

about here I should mention C. McCulloch's new approach to external disk sorting (embodied in the KA Sort on Honeywell 200)

**S.374** stylistic improvements

11/16/77 227

line 17: large, and ... unthinkable!  $\rightsquigarrow$  large; it is, however, so large that  $N$  socks are unthinkable.

line 24: But  $\rightsquigarrow$  On the other hand,

line 24: !  $\rightsquigarrow$  .

**S.381** table entries for Straight insertion

6/14/77 228

Length: 12  $\rightsquigarrow$  10

Space:  $N$   $\rightsquigarrow$   $N + 1$

Average:  $2N^2 + 9N$   $\rightsquigarrow$   $1.5N^2 + 9.5N$

Maximum: 4  $\rightsquigarrow$  3

$N=16$ : 494  $\rightsquigarrow$  412

$N=1000$ : 1985574  $\rightsquigarrow$  1491928

**S.384** insert new paragraph before line -1

6/25/76 229

In Germany, K. Zuse independently constructed a program for straight insertion sorting in 1945, as one of the simplest examples of linear list operations in his "Plankalkül" language. (This pioneering work remained unpublished for nearly 30 years; see *Berichte der Gesellschaft für Math. und Datenv.* 63 (1972), part 4, 84-85.)

**S.387** line 2

8/25/76 230

near-optional  $\rightsquigarrow$  near-optimal

**S.394** caption to Fig. 1

3/ 2/77 231

search.  $\rightsquigarrow$  or "house-to-house" search.

**S.394** Fig. 1

4/19/77 232

label the downward branch coming out of box S3 with an = sign

**S.400** lines 12 and -5

2/28/78 233

running time  $\rightsquigarrow$  average running time

**3.412** correction to previous change 263

4/19/77 234

delete this change, the book was right the first time

**3.413** lines -4,-3

4/19/77 235

and  $N > 2^k$ , we  $\rightsquigarrow$  we  
 $\lceil \lg(N-2^k) \rceil + 1 \rightsquigarrow \lceil \lg(N+1-2^k) \rceil$

**3.419** lines 13-14

3/2/77 236

H. Bottenbruch ... He  $\rightsquigarrow$  D. H. Lehmer [*Proc. Symp. Appl. Math.* 10 (1960), 180-181]  
was apparently the first to publish a binary search algorithm which works for all  $N$ . The  
next step was taken by H. Bottenbruch [*JACM* 9 (1962), 214], who

**3.419** line 30

11/12/76 237

, but his flowchart and analysis were incorrect.  $\rightsquigarrow$  .

**3.429** line 7 (append to step D1)

5/27/78 238

(For example, if  $Q = \text{RLINK}(P)$  for some  $P$ , this means we would set  $\text{RLINK}(P) \leftarrow$   
 $\text{LLINK}(T)$ , etc.)

**3.438** Fig. 16

6/14/77 239

insert "a)" and "b)" to the left of the roots of the trees, and change circles to squares in  
the right descendants of nodes AN and AS in the upper tree

**3.439** update to previous change 276

11/15/78 240

the Garsia-Wachs algorithm appeared in *SIAM J. Computing*, Dec. 1977, pp. 622ff; but  
now it seems an even better way has been found by Hu, Kleitman, and Tamaki (UCSD  
report 78-CS-016)

**3.450** modifications to exercise 33

12/19/76 241

line 6: optimum. Cf.  $\sim$  optimum; cf.

line 7: .)  $\sim$  . On machines which cannot make three-way comparisons at once, a program for Algorithm T will have to make two comparisons in step T2, one for equality and one for less-than; B. Sheil and V. R. Pratt have observed that these comparisons need not involve the same key, and it may well be best to have a binary tree whose internal nodes specify an equality test or a less-than test but not always both. This situation would be interesting to explore as an alternative to the stated problem.)

**3.451** line -3

3/ 2/77 242

put a small inverted U over the *is* in *Akademiis*

**3.456** Fig. 22

9/21/76 243

the arrows between boxes A2 and A3 should be reversed (downward arrow on left, upward arrow on right); also delete "P = A" below boxes A3 and A4 and insert the words "Leaf found" between the two arrows leading to A5

**3.457** line 15

2/28/78 244

necessary.  $\sim$  necessary. Essentially the same method can be used if the tree is threaded (cf. exercise 6.2.2-2), since the balancing act never needs to make difficult changes to thread links.

**3.457** line after (4)

11/29/77 245

K  $\sim$  K

**3.461** Table 1

11/29/77 246

I will recompute this table, since .144 should be .143; also will modify the discussion on page 462 accordingly and will refer to exercise 11

**3.461** line 2 after caption

11/29/77 247

change + and - to typewriter-style type (+ and -)

**3.468** lines 6-9

2/28/78 248

I will rewrite this, as these trees have been studied almost too thoroughly by now

**3.470** exercise 10

11/29/77 249

Does ... c?  $\rightsquigarrow$  What is the asymptotic average number of comparisons made by Algorithm A when inserting the  $N$ th item, assuming that items are inserted in random order?

**3.470** exercise 16

11/29/77 250

the root node F were  $\rightsquigarrow$  node E and the root node F were both

**3.470** new exercise 11

11/29/77 251

[M24] (Mark R. Brown.) Prove that when  $n \geq 6$  the average number of external nodes of each of the types  $+A, -A, ++B, +-B, -+B, --B$  is exactly  $(n+1)/14$ , in a random balanced tree of  $n$  internal nodes constructed by Algorithm A.

**3.472** near the bottom

11/15/78 252

lines -7, -5, -4:  $\log \rightsquigarrow \lg$   
line -3: 350  $\rightsquigarrow$  307

**3.479** update to previous change 293

11/15/78 253

, to appear  $\rightsquigarrow$  9 (1978), 171-181

**3.479** new paragraph before the exercises

12/19/76 254

It is possible for many independent users to be accessing and updating different parts of a large  $B$ -tree file simultaneously without "deadlock," if the algorithms are implemented properly; see B. Samadi, *Inf. Proc. Letters* 5 (1976), 107-112.

**3.483** line 25

7/31/76 255

55  $\rightsquigarrow$  49

**3.486** lines 6 and -2 5/27/78 256

less ~ fewer

**3.491** line -14 5/27/78 257

text, e.g. ~ text; e.g.,

**3.505** line -14 5/27/78 258

to uniquely identify them ~ to identify them uniquely

**3.507** line 13, add new sentence 2/28/78 259

See R. Sprugnoli, *CACM* 20 (1977), 841-850, for a discussion of suitable techniques.

**3.509** line 3 5/27/78 260

superimpose a / over the ■ sign

**3.518** lines 5-7 4/19/77 261

using circular ... complicated. ~ hashing FIRE and searching down its list, as suggested by D. E. Ferguson, since the lists are short.

**3.526** new paragraph after line 19 11/29/77 262

E. G. Mallach [*Comp. J.* 20 (1977), 137-140] has experimented with refinements of Brent's variation, and further recent work on this topic has been done by G. Gonnet and I. Munro [*Proc. ACM Symp. Theory Comp.* 9 (1977), 113-121].

**3.527** insertion of new material after line 20

12/19/76 263

Algorithm R may move some of the table entries, and this is undesirable if they are being pointed to from elsewhere. Another approach to deletions is possible by adapting some the ideas used in garbage collection (cf. Section 2.3.5): We might keep a "reference count" with each key telling how many other keys collide with it; then it is possible to convert unoccupied cells to empty status when their reference count is zero. Alternatively we might go through the entire table whenever too many deleted entries have accumulated, changing all the unoccupied positions to empty and then looking up all remaining keys, in order to see which unoccupied positions really require 'deleted' status. This procedure, which avoids relocation and works with any hash technique, was originally suggested by T. Gunji and E. Goto [to appear].

**3.528** update to previous change 307

11/15/78 264

[To appear.] ~ J. Comp. Syst. Sci. 16 (1978), 226-274.

**3.532** line after (48)

2/28/78 265

likely we, ~ likely, we

**3.534** line -5

3/ 2/77 266

buckets ~ pages or buckets

**3.537** line -8

4/19/77 267

access ~ accesses

**3.544** line 16

6/14/77 268

change one of ~ change

**3.549** exercise 60

1/ 5/79 269

M48 ~ HM41

**3.549** another quote, put above the other 11/16/77 270

*She made a hash of the proper names, to be sure.*  
--GRANT ALLEN, *The Tents of Shem*, Ch. 26 (1889)

**3.561** new paragraph to insert after line 18 3/12/77 271

If carefully selected nonrandom codes are used, it is possible to use superimposed coding without having any false drops, as shown by W. H. Kautz and R. C. Singleton, *IEEE Transactions IT-10* (1964), 363-377; see exercise 16 for one of their constructions.

**3.563** line 11 5/27/78 272

the N\*\*D\*\*E  $\rightsquigarrow$  the form N\*\*D\*\*E

**3.563** line 9 8/25/76 273

his Ph. D. thesis (Stanford University, 1973.)  $\rightsquigarrow$   
*SIAM J. Computing* 5 (1976), 19-50.]

**3.566** Eq. (11) 3/12/77 274

this is all wrong, it should be the 31 sextuples shown in the first printing of vol. 3 on page 565

**3.566** line -7 11/15/78 275

Pfefferneuse  $\rightsquigarrow$  Pfefferneusse

**3.570** line 6 3/12/77 276

systems or  $\rightsquigarrow$  systems on

**3.570** new exercise 3/12/77 277

16. [25] (W. H. Kautz and R. C. Singleton.) Show that a Steiner triple system of order  $v$  can be used to construct  $v(v-1)/6$  codewords of  $v$  bits each such that no codeword is contained in the superposition of any two others.

**3.576** new paragraph after answer 19 11/12/76 278

A similar algorithm can be used to find  $\max\{x_i + x_j \mid x_i + x_j \leq c\}$ ; or to find, e.g.,  $\min\{x_i + y_j \mid x_i + y_j > t\}$  given  $t$  and two sorted files  $x_1 \leq \dots \leq x_m, y_1 \leq \dots \leq y_n$ .

**3.576** line -6 12/19/76 279

junctions;  $\rightsquigarrow$  junctions; STELA, an alternative spelling of 'stele';

**3.579** answer 7, line 3 5/27/78 280

$>B_k$  and append  $(B_k+1)$   $\rightsquigarrow$   $\geq k-B_k$  and append  $k-B_k$

**3.585** new paragraph for answer 8 8/25/76 281

A simple  $O(n^2)$  algorithm to count the number of permutations of  $\{1, \dots, n\}$  having respective run lengths  $l_1, \dots, l_k$  has been given by N. G. de Bruijn, *Nieuw Archief voor Wiskunde* (3) 18 (1970), 61-65.

**3.594** new answer 11/15/78 282

28. This result is due to A. M. Vershik and S. V. Kerov, *Dokl. Akad. Nauk SSSR* 233 (1977), 1024-1028. See also B. F. Logan and L. A. Shepp, *Advances in Math.* 26 (1977), 206-222.

**3.599** exercise 14 line 7 11/29/77 283

13);  $\rightsquigarrow$  13), and still another by the identity in the answer to exercise 5.2.2-16 with  $f(k) = k$ ;

**3.603** exercise 33, comments to program 7/31/76 284

line 07: r12  $\rightsquigarrow$  r13

r13  $\rightsquigarrow$  r12

lines 09 and 15: To L4  $\rightsquigarrow$  To L4 with  $q \leftrightarrow p$

**S.604** replace lines 3 and 4 by the following new copy 6/14/77 285

The  $\infty$  trick also speeds up Program S; the following code suggested by J. H. Halperin uses this idea and the MOVE instruction to reduce the running time to  $(6B + 11N - 10)u$ , assuming that location INPUT+N+1 already contains the largest possible one-word value:

01	START	ENT2 N-1	1
02	2H	LDA INPUT,2	N-1
03		ENT1 INPUT,2	N-1
04		JMP 3F	N-1
05	4H	MOVE 1,1(1)	B
06	3H	CMPA 1,1	B+N-1
07		JG 4B	B+N-1
08	5H	STA 0,1	N-1
09		DEC2 1	N-1
10		J2P 2B	N-1

Doubling up the inner loop would save an additional  $B/2$  or so units of time.

**S.605** exercise 4 2/28/78 286

lower the  $\Sigma$  sign and the relation below it

**S.606** line 10 of the program 2/28/78 287

$rA \rightsquigarrow rA$

**S.606** answer 11 11/29/77 288

In general, ... elements.  $\rightsquigarrow$  The situation becomes more complicated when  $N = 64$ ; R. Sedgewick has shown how to compute the worst-case permutations, and he has proved that the maximum number of exchanges is  $1 - \lg \lg N / \lg N + O(1/\log N)$  times the number of comparisons [*SIAM J. Computing*, to appear].

**S.607** new answer 16

11/29/77 289

16. Consider the  $\binom{2n}{n}$  lattice paths from  $(0,0)$  to  $(n,n)$  as in Figs. 11 and 18, and attach weights  $f(i-j)$  if  $i \geq j$ ,  $f(j-i-1)+1$  if  $i < j$ , to the line from  $(i,j)$  to  $(i+1,j)$ ; here  $f(k)$  is the number of bits  $b_r \neq b_{r+1}$  in the binary expansion  $k = (\dots b_2 b_1 b_0)_2$ . The total number of exchanges on the final merge when  $N = 2n$  is

$$\sum_{0 \leq j < i < n} (2f(j)+1) \binom{2i-j}{i-j} \binom{2n-2i+j-1}{n-i-1}.$$

R. Sedgewick has simplified this sum to

$$(1/2)n \binom{2n}{n} + 2 \sum_{k \geq 1} \binom{2n}{n-k} \sum_{0 \leq j < k} f(j) \text{ and used the gamma function method to obtain}$$

the asymptotic formula  $\binom{2n}{n} \{ (1/4)n \lg n + (\lg(\Gamma(1/4)^2/2\pi) + 1/4 - (\gamma+2)/(4 \ln 2) + \delta(n))n + O(\sqrt{n \log n}) \}$ , where  $\delta(n)$  is a periodic function of  $\lg n$  with magnitude bounded by .0005; hence about 1/4 of the comparisons lead to exchanges, on the average, as  $n \rightarrow \infty$ . [SIAM J. Computing, to appear.]

**S.610** second line of answer 31

11/29/77 290

step  $\rightsquigarrow$  stop

**S.611** last line of answer 37

2/28/78 291

.  $\rightsquigarrow$  .]

**S.612** exercise 48 line 4 in limits to the integral

2/28/78 292

$1/2 \rightsquigarrow -1/2$  (twice)

**S.616** line 26 of the program

2/28/78 293

$rA \rightsquigarrow rA$

**S.618** answer 20 line 2

5/27/78 294

$0 \leq q < k \rightsquigarrow 0 \leq q \leq k$

**S.619** answer 27 line 1

5/27/78 295

$d \setminus n \rightsquigarrow d \setminus N$

**S.627** line 16

11/5/79 296

See also  $\rightsquigarrow$  See also P. A. MacMahon, *Proc. London Math. Soc.* (1891), 341-344;

**S.627** bottom of page, new paragraph for answer 6

8/25/76 297

M. Paterson observes that if the multiplicities of keys are  $\{n_1, \dots, n_m\}$ , the number of comparisons can be reduced to  $n \lg n - \sum n_i \lg n_i + O(n)$ ; see *SIAM J. Computing* 5 (1976), 2.

**S.630** answer 20

5/27/78 298

line 5:  $l-1 \rightsquigarrow l+1$   
line 6:  $2^{-l+1} \rightsquigarrow 2^{-l}$   
line 6:  $2^{-l} \rightsquigarrow 2^{-l-1}$   
line 6:  $2^l \rightsquigarrow 2^{l+1}$  (twice)  
line 7:  $\lfloor \lg N \rfloor + 1 \rightsquigarrow \lfloor \lg N \rfloor$

**S.634** exercise 6

11/29/77 299

$\lg(\dots) \rightsquigarrow \lceil \lg(\dots) \rceil$

**S.635** answer 10

3/2/77 300

[*Inf. Proc. Letters*  $\rightsquigarrow$   
]  $\rightsquigarrow$  .

**S.637** supplement to new answer 22

9/21/76 301

[See C. K. Yap, *CACM* 19 (1976), 501-508, for a further improvement.]

**3.637** new answer

12/19/76 302

25. (a) Let the vertices of the two types of components be designated  $a; b < c$ . The adversary acts as follows on nonredundant comparisons: Case 1,  $a:a'$ , make an arbitrary decision. Case 2,  $x:b$ , say that  $x > b$ ; all future comparisons  $y:b$  with this particular  $b$  will result in  $y > b$ , otherwise the comparisons are decided by an adversary for  $U_t(n-1)$ , yielding  $\geq 2+U_t(n-1)$  comparisons in all. This reduction will be abbreviated "let  $b = \min; 2+U_t(n-1)$ ." Case 3,  $x:c$ , let  $c = \max; 2+U_{t-1}(n-1)$ .

(b) Let the new types of vertices be designated  $d_1, d_2 < e; f < g < h > i$ . Case 1,  $a:a'$  or  $c:c'$ , arbitrary decision. Case 2,  $a:c$ , say that  $a < c$ . Case 3,  $x:b$ , let  $b = \min; 2+U_t(n-1)$ . Case 4,  $x:d$ , let  $d = \min; 2+U_t(n-1)$ . Case 5,  $x:e$ , let  $e = \max; 3+U_{t-1}(n-1)$ . Case 6,  $x:f$ , let  $f = \min; 2+U_t(n-1)$ . Case 7,  $x:g$ , let  $f$  and  $g = \min; 3+U_t(n-2)$ . Case 8,  $x:h$ , let  $h = \max; 3+U_{t-1}(n-1)$ . Case 9,  $x:i$ , let  $i = \min; 2+U_t(n-1)$ .

(c) For  $t = 1$  we have  $U_1(n) = n-1$ , so the inequality holds. For  $1 < t \leq n/2-1$ , use induction and (b). For  $t = (n-1)/2$ , use induction and (a). For  $t = n/2$ ,  $U_t(n-1) = U_{t-1}(n-1)$ ; use induction and (a). Exercise 14 now yields the following lower bound for the median:  
 $V_t(2t-1) \geq 3t + Lt/2 - 4$ .

**3.640** update to previous correction number 345

2/28/78 303

(To appear.)  $\rightsquigarrow$  *IEEE Trans. C-27* (1978), 84-87.

**3.641** line -2

1/16/77 304

Pollard.]  $\rightsquigarrow$  Pollard.] All such identities can be obtained from a system of four axioms and a rule of inference for multivalued logic due to Łukasiewicz; see Rose and Rosser, *Trans. Amer. Math. Soc.* **87** (1958), 1-53.

**3.641** exercise 43

3/12/77 305

A. Waksman and M. Green have proved that  $\rightsquigarrow$  By slightly extending a construction due to L. J. Goldstein and S. W. Leibholz, *IEEE Trans. EC-16* (1967), 637-641, one can show that  $P(n) \leq P(\lfloor n/2 \rfloor) + P(\lceil n/2 \rceil) + n - 1$ , hence Eq. 5.3.1-3, cf. ... Green also has proved  $\rightsquigarrow$  Eq. 5.3.1-3; M. W. Green has proved (unpublished)

**3.642** line 14

5/27/78 306

$\leftarrow \rightsquigarrow \rightarrow$

**3.645** new paragraph after answer 10

2/28/78 307

One might complain that the algorithm compares KEY values that haven't been initialized. If such behavior is too shocking, it can be avoided by setting all KEYs to 0, say, in step R1.

**3.658** line 7

5/27/78 308

increase  $l$  by 1, set ..., and return  $\rightsquigarrow$  set ..., increase  $l$  by 1, and return

**3.665** exercise 3 line 7

11/12/76 309

Trabb-Pardo  $\rightsquigarrow$  Trabb Pardo

**3.671** exercise 2

2/28/78 310

line 1: RTAG  $\rightsquigarrow$  RTAG(Q)

line 2: RLINK(P).  $\rightsquigarrow$  RLINK(P) and RTAG(P)  $\leftarrow +$ . In step T4, change the test RLINK(P)  $\neq \Lambda$  to RTAG(P)  $\neq +$ .

last line: .]  $\rightsquigarrow$  . Similar remarks apply with simultaneous left and right threading.]

**3.673** tree illustration in answer 23

11/15/78 311

5  $\rightsquigarrow$  9

**3.675** new answer 11

11/29/77 312

11. Clearly there are as many +A's as --B's and +-B's, when  $n \geq 2$ , and there is symmetry between + and -. If there are  $M$  nodes of types +A and -A, consideration of all possible cases when  $n \geq 1$  shows that the next random insertion produces  $M-1$  such nodes with probability  $3M/(n+1)$ , otherwise it produces exactly  $M+1$  such nodes. The result follows. [To be published.]

**3.676** new answer to exercise 16

11/29/77 313

Delete E; Case 3 rebalancing at D. Delete G; replace F by G; Case 2 rebalancing at H; balance factor adjusted at K.  
(a new illustration, in the same style as before, must be supplied now)

**S.677** answer 20

8/25/76 314

the line following the tree should become the following (instead of what was stated in the former correction number 355):

It is perhaps most difficult to insert a new node at the extreme left of a tree like this. An insertion algorithm taking at most  $O(\log n)^2$  steps has been presented by D. S. Hirschberg, *CACM* 19 (1976), 471-473.

**S.678** update to previous change 678

11/15/78 315

, to appear  $\sim$  9 (1978), 171-181

**S.679** changes to answer 5

6/14/77 316

450. The worst ... chars.  $\sim$

Interpretation 1, trying to maximize the stated minimum: 450. (The worst ... chars.)

Interpretation 2, trying to equalize the number of keys after splitting, in order to keep branching factors high: 155 (15 short keys followed by 16 long ones).

**S.680** bottom, new paragraph for answer 4

7/31/76 317

A more versatile way to economize on trie storage has been proposed by Kurt Maly, *CACM* 19 (1976), 409-415.

**S.684** line -8

2/28/78 318

$n \sim N$

**S.687** exercise 1

2/28/78 319

-38  $\sim$  -37

**S.687** answer 4

6/14/77 320

change line 1 to: Consider cases with  $k$  pairs. The smallest  $n$  such that  
in line 2 (the displayed formula), interchange  $m$  and  $n$  everywhere, then add ", for  $m = 365$ ,"

**3.687** update to previous change number 365

6/14/77 321

Computing, to appear.  $\rightsquigarrow$  Computing 6 (1977), 201-234.

**3.688** new answer

12/19/76 322

10. See F. R. K. Chung and R. L. Graham, *Ars Combinatoria* 1 (1976), 57-76.

**3.689** exercise 14

6/14/77 323

line 2: keys  $\rightsquigarrow$  all keys

line 12: until  $\rightsquigarrow$  until TAG (P) = 1 and

line 12: points  $\rightsquigarrow$  points (perhaps indirectly through words with TAG = 2)

**3.693** replace all but first line of answer 37 by:

12/19/76 324

$$\begin{aligned} M^N N S_N &= \frac{1}{3} \sum_{k_1, \dots, k_M} \binom{N}{k_1, \dots, k_M} (k_1(k_1 - \frac{1}{2})(k_1 - 1) + \dots + k_M(k_M - \frac{1}{2})(k_M - 1)) \\ &= \frac{1}{3} M \sum_k \binom{N}{k} (M-1)^{N-k} k(k - \frac{1}{2})(k - 1) \\ &= \frac{1}{3} M N(N-1)(N-2) \sum_k \binom{N-3}{k-3} (M-1)^{N-k} + \frac{1}{2} M N(N-1) \sum_k \binom{N-2}{k-2} (M-1)^{N-k} \\ &= \frac{1}{3} M N(N-1)(N-2) M^{N-3} + \frac{1}{2} M N(N-1) M^{N-2}. \end{aligned}$$

The variance is  $S_N - ((N-1)/2M)^2 = (N-1)(N+6M-5)/12M^2 \approx \frac{1}{2}a + \frac{1}{2}a^2$ .

**3.698** new answer

1/ 5/79 325

60. No; see M. Ajtai, J. Komlós, and E. Szemerédi, *Inf. Proc. Letters* 7 (1978), 270-273.

**3.700** new answer

3/ 2/77 326

16. Let each triple correspond to a codeword, where each codeword has exactly three 1 bits, identifying the elements of the corresponding triple. If  $u, v, w$  are distinct codewords,  $u$  has at most two 1 bits in common with the superposition of  $v$  and  $w$ , since it had at most one in common with  $v$  or  $w$  alone. [Similarly, from quadruple systems of order  $v$  we can construct  $v(v-1)/12$  codewords, none of which is contained in the superposition of any three others, etc.]

**3.703** update to previous correction number 373

11/12/76 327

appear in the  $\rightsquigarrow$  appear in Eq. 5.2.3-19 and in the

**S.710L**

11/5/79 328

Ajtai, Miklos, 698.

**S.710L**

11/16/77 329

Allon, Charles Grant Blairfindie, 549.

**S.710L**

4/19/77 330

add p576 to AND entry

**S.711**

11/15/78 331

delete index entries for R. M. Baer and P. Brock

**S.711B**

11/29/77 332

Brown, Mark Robbin, 470.

**S.712L**

4/19/77 333

delete Circular lists entry

**S.712L**

12/19/76 334

Chung, Fan Rong King, 688.

**S.712B** de Bruijn entry

8/25/76 335

add p. 585

**S.712B**

12/19/76 336

Deadlock, 479.

**S.71S**

6/14/77 337

accent over o in Erdős should be " not "

**S.71SL**

1/16/77 338

Drysdale, Robert Lewis (Scot), III, 239.

**S.71SR**

4/19/77 339

add p576 to Exclusive or entry

**S.71SR**

1/12/76 340

Espelid, Torje Oskar, 259.

**S.714L**

4/19/77 341

add p518 to Ferguson entry

**S.714L** line 5

9/21/76 342

Feurnig ~ Feurneig

**S.714R**

2/28/78 343

Gonnet Haas, Gaston Henry, 526.

**S.714R**

3/ 2/77 344

Goldstein, Larry Joel, 641.

**S.714R**

6/14/77 345

Halperin, John Harris, 604.

**S.714R**

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A-ordered, 86-92, 103-104, see 2-ordered.  
A-sorting, 86-92.

**S.714R**

11/29/77 347

add p607 to Gamma function entry

**S.714R**

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Goto, Eiichi, 527.

**S.714R**

12/19/76 349

Gunji, Takao, 527.

**S.715L**

4/19/77 350

Index mod  $p$ , 9.

**S.715L**

9/21/76 351

Hirschberg, Daniel Syna Moses, 677.

**S.715R** new entry

5/27/78 352

Interchanging blocks of data, 598 (exercise 6), 664 (exercise 3).

**S.716L**

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Komlós, János, 698.

**S.716L** Kleitman entry

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640 ~ 639

**S.716L**

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Lehmer, Derrick Henry, 419.

**S.716L**

31 2/77 356

add pp. 561, 570 to Kauts entry

**S.716L**

11/15/78 357

Kerov, S. V., 594.

**S.716R**

11/16/77 358

add p641 to Łukasiewicz entry

**S.716R**

31 2/77 359

Leibholz, Stephen W., 641.

**S.716R**

6/25/76 360

Lozinskiĭ, Eliezer Leonid Solomonovich, 621.

**S.717L** MacMahon entry

11 5/79 361

add p. 627

**S.717L**

7/13/76 362

Maly, Kurt, 680.

**S.717L**

11/29/77 363

Mallach, Efrem Gershon, 526.

<b>S.717L</b>	12/19/76 364
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<b>S.717R</b>	2/28/78 365
Munro, James Ian, 526.	
<b>S.717R</b>	5/27/78 366
Mahon, Maurice Hartland (= Magenta), ix.	
<b>S.717R</b>	6/14/77 367
MOVE, 604.	
<b>S.718L</b>	3/ 2/77 368
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<b>S.718L</b>	4/19/77 369
delete Newell entry	
<b>S.718L</b>	12/19/76 370
Nitty gritty ~ Nitty-gritty	
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Packed data, 401.	
<b>S.718R</b> new entry	5/27/78 372
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**S.718R** Paterson entry

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add p. 627

**S.719L**

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**S.719R**

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Rose, Alan, 641.  
Rosser, John Barkley, 641.

**S.719R**

3/1 2/77 376

Rearrangeable network, see Permutation network.

**S.719R** new entry

5/27/78 377

Rotation of data, 598.

**S.720L**

11/29/77 378

add pp. 606, 607 to Sedgewick entry

**S.720L**

12/19/76 379

Samadi, Behrokh, 479.

**S.720L**

12/19/76 380

add p. 220 to Schönhage entry

**S.720R**

3/1 2/77 381

add pp. 561, 570 to Singleton entry

<b>3.720R</b> entry for SLB	8/25/76 382
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Sheil, Beaumont Alfred, 450.	
<b>3.721L</b>	2/28/78 384
Sprugnoli, R , 507.	
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<b>3.722L</b>	11/12/76 389
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**3,722R**

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Wiener, Norbert, 8.

**3,722R**

3/ 2/77 393

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**3,722R**

4/19/77 394

Wang, Yihsiao, 128.

**3,722R** new names

6/25/76 395

Venn, John L.  
Windley, Peter F.

**3,722R**

11/12/76 396

Yap, Chee-Keng, 637.

**3,722R**

11/15/78 397

Vershik, Anatoliĭ Moiseevich, 594.

**3,723R**

6/14/77 398

2-ordered, 87, 103, 112, 135.

**3,726** (namely the endpapers of the book)

4/19/77 399

also make any changes specified for pages 136-137 of volume 1

3.749L

12/19/76 400

add p. 450 to Vaughan Pratt entry

3.765 addendum to previous change 324

11/15/78 401

John M. Pollard has discovered an elegant method for index computation in about  $O(\sqrt{p})$  operations mod  $p$ , requiring very little memory, based on the theory of random mappings. See *Math. Comp.* 32 (1978), 918-924, where he also suggests another method based on numbers  $n_j = r^j \bmod p$  that have only small prime factors.

9.0 changes for the book Mariages Stables

11/177 402

- p12 line 18:  $\Lambda c \rightsquigarrow \Lambda a$   
 p14 line 4:  $Ab \rightsquigarrow Bb$   
 p18 line -5:  $B_i \rightsquigarrow B_j$  and  $A_i \rightsquigarrow A_j$  (four changes)  
 p18 line -4:  $b_i \rightsquigarrow b_j$  and  $a_i \rightsquigarrow a_j$  (four changes)  
 p18 line -3:  $a_n \rightsquigarrow a_k$   
 p22 line -5, -4, -3:  $d: \rightsquigarrow b: b: \rightsquigarrow c: c: \rightsquigarrow d:$   
 p32 line 6: exercices  $\rightsquigarrow$  exercices  
 p32 line -5 exercise  $\rightsquigarrow$  exercice  
 p35 illustration: delete arc from 4 of clubs to 8 of hearts  
 p38 line -11:  $C \rightsquigarrow B$   
 p47 line 2: Chebyshev  $\rightsquigarrow$  Tchébichev  
 p50 lines -12, -10, -3 and p51 line 5: Chebyshev  $\rightsquigarrow$  Tchébichev  
 p52 line -6:  $c \rightsquigarrow C$   
 p65 line -4:  $m \rightsquigarrow m$   
 p66 line -10, denominator of third term in sum:  $n+1 \rightsquigarrow n-1$   
 p71 line 8: que  $R_{\Lambda} = \rightsquigarrow$  que  
 p74 line -1:  $X \rightsquigarrow x$   
 p78 line -7:  $X \rightsquigarrow x$   
 p78 line -4:  $Q[\Lambda] \rightsquigarrow Q[i]$   
 p86 line 10: femmes.  $\rightsquigarrow$  femmes?  
 p87 line -10:  $ZZ' \rightsquigarrow Zs'$   
 p92 line -8: exercice  $\rightsquigarrow$  exercice  
 p93 line 4: et  $(\Lambda a, Bb, Cc \rightsquigarrow$  et  $(\Lambda a, Bc, Ch$   
 p93 lines -6, -3, -2: crossed-out  $e$  should be crossed-out  $c$   
 p95 line 3:  $n!P_n \rightsquigarrow n!p_n$   
 p95 line 9:  $\Sigma \rightsquigarrow \Sigma_i$   
 p95 line -2: formula should be preceded by (3)  
 p95 line -2:  $dx_2 \dots dx_n dy_1 dy_2 \dots dy_n \rightsquigarrow dx_2 \dots dx_n dy_1 dy_2 \dots dy_n$

## 9.1 Changes for Surreal Numbers

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p86 lines 13-14 should say:  $II(y, X_{L,s}), II(Y_{R,s}, s)$ .

p86 line -2, change final comma to a period

p86 line -1, delete this line

p112 line -5: p. The  $\sim$  p. [See his incredible book *On Numbers and Games*, published by Academic Press in 1976.] The

p113 *Mathematik*  $\sim$  *Analysis*

THE TEX/METAFONT PROJECT.

WHAT HAS BEEN DONE:

Don Knuth has finished (and frozen) the implementation of TEX (the typesetting system) and is currently involved in the implementation of METAFONT (the font generator).

WHAT WE WANT TO DO:

We want to complement TEX / METAFONT with a suitable hardware environment, namely:

- \* An XGP type device that will provide hardcopy capabilities both for proofreading and for (medium quality) originals.
- \* A high resolution typesetting device for high quality originals.
- \* A high resolution CRT terminal, capable of displaying TEX output.

We also want to make the system widely available, thus it is needed to implement it in a more widespread language (PASCAL).

And finally we would like to try our hand in making TEX more interactive than what it is now. (This one is a tougher cookie.)

IF YOU ARE INTERESTED:

There are many things to be done. There are learning opportunities. There are academic goodies (units, CS293 projects, etc). And there is also monies.

FOR MORE INFO:

Send a message to LTP, or call 74425 or 74377.